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ABSTRACT

The purpose of this study was to identify the most important factors related to the problem of women's participation in mathematics and to determine the relative importance of the factors to guide future research and intervention efforts. The vehicle for this study was a national survey of 1,452 13-year-olds and 1,788 high school seniors. The data collection centered upon achievement in mathematics, participation in mathematics, sex-role stereotyping, career and academic plans, the student's attitude toward mathematics, parental influence and the influence of significant other people in the student's life. Correlation and regression analyses were performed on the survey data to identify those factors which most affect participation and achievement in mathematics. The results of the study indicate that 13-year-old females start their high school mathematics career with at least the same ability as their male contemporaries. By the twelfth grade, males have overtaken females. The results also indicate that certain groups of variables open to intervention strategies are related to participation and that these variables predict participation. At the conclusion of this report, strategies are suggested which may increase mathematics participation in school programs. (Author/MK)

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Achievement and Participation of Women In Mathematics: An Overview

Report of a Two-Year Study Funded by the National Institute of Education
Report 10-MA-00

By:

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March 1980

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ABSTRACT

The purpose of this study was to identify the most important factors related to the problem of women's participation in mathematics and to determine the relative importance of those factors to guide future research and intervention efforts. The vehicle for the study was a national survey of 1,452 13-year-olds and 1,788 high school seniors. The data collection centered upon achievement in mathematics, participation in mathematics, sex-role stereotyping, career and academic plans, the student's attitudes toward mathematics, parental influence and the influence of significant other people in the students' lives. Correlation and regression analyses were performed on the survey data to identify those factors which most affect participation and achievement in mathematics.

The results of the study indicate that 13-year-old females start their high school mathematics career with at least the same ability as their male contemporaries. In fact, 13-year-old girls are better at computation and spatial visualization than males. Their problem-solving skills are nearly equal.

By the twelfth grade, males have overtaken females. Males excel in problem-solving but have abilities in spatial visualization and computation comparable to those of their female counterparts. The hypothesis that males dominate mathematics because they have a superior ability in spatial visualization is not supported by the study results. For twelfth graders, no sex differences were found for spatial visualization.

The large sex differences found for mathematics participation in previous studies were not found in this national survey. It was also found that most of the factors which seem to affect participation for the older group are the same for males as well as females.

The results also indicate that certain groups of variables open to intervention strategies are related to participation and that these variables predict participation. Three groups of variables were found to have the greatest effect on participation:

- positive attitudes toward mathematics
- perceived need for mathematics for future career and educational plans
- influences of significant others, including parents, teachers and counselors

The results imply that intervention strategies aimed at instilling and sustaining the positive influences of these factors are good prospects for maximizing participation in mathematics.

At the conclusion of this report, strategies are suggested which may increase mathematics participation in school programs. All of these strategies could have significant influence in assuring that mathematics attracts both males and females.

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Administration of the survey was conducted by the Research Triangle Institute, Raleigh, North Carolina. Scoring and processing were carried out by Westinghouse DataScore Systems, Iowa City, Iowa, and by the National Assessment staff.

Numerous members of the National Assessment staff contributed their expertise to various aspects of this study. Special thanks must go to the following people: Nancy Burton for her assistance in conceptualizing the study; Stuart Kahl for his work on the development of the survey; Dunlap Scott for the coordination of the administration with the Research Triangle Institute; Susan Sullivan for the coordination of the scoring with DataScore Systems; Donald Searls, Gene Johnson and Alex Pearson for assistance in statistical techniques; John Kalk, Ingrid Larsson and Arlen Price for computer program development and data processing support; Ted Pratt for the production of this report; and Roy Forbes for his continuous support for the duration of this project.

INTRODUCTION

Among U.S. women who pursue a career outside the home, very few choose roles in science, engineering or medicine.

Social, educational and cultural barriers have prevented women from entering such technical fields. These barriers have existed for years, and despite hopeful rhetoric, they have changed little during the last half century. Only one-tenth of one percent of engineers are women; only two percent of physicists are women; only five percent of chemists are women.

Many factors work against women's entry into technical fields. For example, most technical pursuits require training in college-level mathematics. Without such training, women are barred. However, women's mathematics course-taking deficiency begins long before college and, by the time most women reach college, they do not have the mathematics background necessary for technical careers. According to a 1978 report from the College Entrance Examination Board, approximately 63 percent of college-bound males had taken four or more years of high school mathematics. Only 43 percent of females were similarly qualified. In most colleges and universities, four years of high school mathematics are required to take calculus—which is in turn required for virtually every technical or scientific major. Thus, without remedial work, more than half of all college-bound women are unable to major in the technical fields.

Why do women often avoid careers that require a foundation of mathematics? It is generally accepted that elementary school girls excel in arithmetic and science. However, the picture begins to change in junior high school as boys overtake and pass their female contemporaries in mathematics achievement. From the eighth grade on, female participation in mathematics declines steadily until, by high school graduation, male students outnumber women in mathematics classes.

Most of the large-scale research studies conducted in the last 20 years on sex differences in mathematics achievement and participation focused on these facts to support an underlying premise that since males traditionally take more mathematics they, therefore, tend to have higher achievement scores.

Traditional attempts to explain women's lack of participation in mathematics have viewed mathematics, a discipline characterized by abstract logic and deductive thought, as basically unfeminine. Through the ages mathematics has been regarded as a male domain. Women supposedly shy away from the logic and deductive thought required by mathematics in favor of aesthetic beauty and intuitive thought.

In fact, in earlier ages it was believed that women could not pursue mathematics because, for example, their heads were too small, their nervous systems too delicate or their reasoning capacities insufficient. Such an eminent educational theorist as Rousseau believed that women were not qualified for research in abstract areas such as mathematics and science because their brains were unfit.

While such notions are clearly passé, they do have 20th century counterparts. For example, the possibility of a genetic effect favoring males in the area of spatial visualization is currently a topic under investigation. Is there a genetic barrier against female participation in mathematics? Or do society's preconceptions condition women against excelling in mathematics?

Preconceptions can be manifested in many factors in a young woman's environment. The interaction of these factors may work to help or hinder her in mathematical progress. Identifying and examining these factors and their interaction was one of the objectives that the National Institute of Education addressed with the Women and Mathematics grant program. Specifically, the program was designed to "identify and explain how selected cognitive, affective, educational,

familial or social factors influence achievement and participation of women...in their study of mathematics, their attitudes toward the study and usefulness of mathematics and their preferences for occupations requiring mathematical competence."

This study was conducted by the Education Commission of the States (ECS) as a part of the Women and Mathematics program to identify the most important factors related to the problem of women's participation in mathematics and, further, to explore the relative importance of those factors in an effort to guide future research and to aid the development of strategies to remove the bias against women in the world of mathematics.

The survey approach used in this study is particularly appropriate for a complex problem such as women's participation and achievement in mathematics where the diversity of factors and their relationships may offer numerous plausible explanations. Previous studies reflect a clear lack of agreement regarding the effect of many of the variables on participation. Most of these studies looked at only a few of the possible affective factors at one time. Further, the sample sizes were small and the results frequently inconclusive due to a lack of statistical power. A national sample such as that used in the current study is one way to resolve the conflicts produced by previous limited samples. A large-scale survey can detect the small but stable influences overlooked by smaller, less sensitive studies. Thus, a major significance of the study reported here will be the determination for the relative importance of each of the possible factors affecting women's participation in mathematics based on national data.

RELATED RESEARCH

The findings of previous research on women's participation and achievement in mathematics were instrumental in defining the present study. Brief summaries of research findings are presented for each of the variables used in this study.

Mathematics Achievement

Most of the large-scale studies performed during the sixties and seventies found significant sex differences in achievement beginning at puberty and continuing through adulthood, with males generally having superior scores (*Mathematical Applications*, 1979; *The First National Assessment of Mathematics: An Overview*, 1975; Wilson, 1972; Fennema and Sherman, 1977; Schonberger, 1976).

Mathematics Participation

Unfortunately, mathematics course-taking or participation was not controlled in most of the previous studies on sex differences in achievement. However, several recent studies have focused on the question of sex-related differences in participation. Differential enrollment patterns in mathematics begin to appear at the level of Algebra II, and increase thereafter (Fennema, 1977). One study performed at the University of California found that among entering freshmen, males who had taken four years of high school mathematics outnumbered females by more than 7 to 1 (Sells, 1973). Fennema (1977) found a 2 to 1 ratio in advanced mathematics classes.

Sex-Role Stereotyping

A number of studies have attempted to determine the relationship between sex-role stereotyping and mathematics participation by women. These studies suggest that many females regard careers for themselves as incompatible with family responsibilities. In general, it appears that if a woman anticipates a conflict between a career and the traditional role of homemaking, she is much more likely to choose the traditional role (Astin, 1974; Rossi, 1965). Additionally, Ory and Helfrich (1976) found that women seeking professional careers were less traditional in their views of women's sex-role identity than women choosing nonprofessional careers.

Mathematics as a Male Domain

Several studies have centered upon the sex-typing of mathematics as a "male domain" — a field of study and work appropriate only for males. In general, researchers have found that girls experience a strong conflict between academic achievement and popularity, in many cases choosing not to pursue mathematics because it might hamper their social relationships with boys (Coleman, 1961; Hawley, 1971, 1972; Komarovsky, 1946; Lavach and Lanier, 1975; Fennema and Sherman, 1977; Sherman and Fennema, 1977).

Other research studies have focused upon the masculine identity hypothesis. That is, boys and girls who identify with their fathers or the male sex-role are better at mathematics. However, the results here are contradictory (Block, 1973; Heilbrun, 1974; Plank and Plank, 1954).

Career and Academic Plans

It appears that many college women may shun mathematics study because of a perceived conflict of roles (Smith, 1976). A science or mathematics career could interfere with raising a family and might conflict with the husband's career. Hawley (1971, 1972) and Astin (1974) found that marriage was the primary goal of most women and, in choosing a career, the women based much of their decision on what they believed men could or would tolerate

Attitude Toward Mathematics

A student's feelings toward mathematics can be a strong influence in his or her decision to continue with or begin to avoid mathematics. Enjoyment, confidence and anxiety about mathematics combine to reflect the student's attitude toward mathematics.

In addition, the perceived usefulness of mathemat-

ics is an important factor in shaping the student's view of the subject. Several studies have found sex differences in students' perception of the usefulness of mathematics (Fennema and Sherman, 1976; Fox, 1975; Hilton and Berglund, 1974; Sherman and Fennema, 1977; Haven, 1971). In general these studies suggest that women who believe that mathematics would be useful in their future studies are much more likely to continue to take mathematics courses.

Parental Influence

Research suggests that parental influence strongly affects a student's course-taking, achievement in mathematics and career aspirations through role modeling, direct encouragement and expression of positive attitudes toward mathematics. Parental factors that have been found to mold the students' attitudes toward mathematics most strongly are the parents' enjoyment, confidence with and use of mathematics. However, the exact nature of the parental influence is not clear from the research. Poffenberger and Norton (1956) found that male students were more prone to like mathematics if the father both liked mathematics and was good at it. This was not generally true for daughters, however.

Fennema (1977) noted that students' perception of their parents' attitudes were related to the students' course-taking intentions. Parental expectations seemed to influence students' success in mathematics, although parents appeared to have lower expectations for daughters than for sons (Poffenberger and Norton, 1956; Hill, 1967; Levine, 1976; Casserly, 1975). Fox (1976) concluded that the expectations of the father, but not his attitude or occupation, influenced mathematics achievement for girls. Poffenberger and Norton (1956) found that, while the mother's expectations were important, her liking of mathematics was not. This was true for both sons and daughters (Burbank, 1968).

Influence of Other Significant People

A considerable amount of evidence indicates that the student's peers, counselors and teachers exert a strong influence on the student's view of mathematics.

A considerable amount of evidence suggests that girls are seriously concerned about negative consequences of academic success, especially in mathematics. Even highly competent and achievement-motivated young women usually put their "femininity" before their academic success when conflict between the two images would arise (Horner, 1972).

Counselors appear to have a negative or neutral effect on girls who want to pursue mathematics or professional careers (Casserly, 1975, 1979). In some cases, counselors advised further counseling when girls wanted to pursue nontraditional careers and often discouraged girls from pursuing mathematics (Thomas and Stewart, 1971).

Many studies indicate that students' attitudes toward mathematics are strongly influenced by their experience with teachers. Students tend to be swayed by what they believe the teacher thinks of them and their ability in mathematics (Fennema and Sherman, 1976). The seriousness of this influence on women's participation in mathematics is reflected by the fact that, in many cases, teachers tend to treat boys and girls differently (Bean, 1976; Parsons, 1979).

On the other hand, at least two studies showed that teachers can have a tremendous positive influence on women's participation in mathematics. Casserly (1975) found that in high schools which had high female enrollment in advanced placement physics and mathematics, the teachers had actively recruited girls for their courses. Luchins (1976) found that many women successful in mathematics had at least one encouraging teacher during their education.

METHODOLOGY

Having reviewed previous work on the network of interrelated factors affecting achievement and participation in mathematics, the present study isolated and defined each factor for the development of measures to use in the subsequent survey.

Defining the Variables

Based on a thorough literature search, a tentative list of variables which might affect participation was developed. Relevant research articles and existing instruments were reviewed by staff and definitions of each variable were drafted. Following this review, a rough first draft of scales or individual items for each of the variables of interest was prepared by staff for consideration by a five-member advisory board. The board, comprised of three mathematics educators and two research psychologists, was formed to give its reaction to products and plans and to advise the project staff. The advisory board refined definitions of the variables and reviewed existing instruments for accuracy, completeness, item quality and content validity.

In February 1978 all items and scales were field tested on approximately 500 eighth grade and 500 twelfth grade students from Duluth, Minnesota, and Columbus, Georgia. These sites were selected to represent the national average based on the sampling plan developed by the National Assessment.

Following the two initial field tests, the advisory board reviewed the results and recommended those items which should be included in the final survey. Consultants then reviewed the selected items and filled in gaps where items had been deleted or refinements had been made in the definition of the variables. In April of 1978, the instruments were again field tested, this time on 900 eighth and eleventh grade students in Minnesota, Rhode Island and Connecticut.

Following the April field tests, items were analyzed once again, and the weaker items (based on item-to-scale correlations and standard deviations) were rejected. Also at this stage, items were rejected if they were repetitious.

Sampling

The drawing of the survey sample and the administration of the questionnaire were performed under subcontract by the Research Triangle Institute (RTI), Research Triangle Park, North Carolina. The sample was drawn in the early spring of 1978 and the survey administered between October 9 and December 15, 1978.

An attempt was made to identify the most important factors affecting women's participation and achievement in mathematics by bracketing the time when changes occur. Thirteen-year-olds were one data base since most 13-year-olds are in the eighth grade, the point where required mathematics generally ends. Seniors in high school were selected as the other sample. Here, students will have completed or be completing their high school mathematics careers. The survey was administered to these two groups to detect shifts or changes in attitudes and achievement in mathematics during the high school years.

The sample for the 13-year-old population included 82 schools, with group administration sizes ranging from 12 to 25 students; 1,452 13-year-olds were surveyed. For twelfth grade students, the sample consisted of 71 schools and 1,788 students. As many as 35 students per school were surveyed.

The larger sample size for high school seniors was a result of oversampling. It was feared that, in a national probability sample, there might be insufficient advanced females, and possibly advanced males, to form a group large enough for statistical comparisons. Thus, students who had taken Trigonometry or higher-level mathematics courses were considered "advanced" and were oversampled. In the statistical analysis, weights were used to represent the occurrence of the various types of students in the nation.

Administration

Students were paced through the 90 minute survey by an audio tape to assure they would finish answering all questions and to put a time limit on the achievement items included in the survey.

Answer sheets were scanned by Westinghouse DataScore Systems and the results put on computer tapes. A weight for each respondent was computed by RTI and these data were merged onto the data tape. The weighted tape was then sent to ECS for analysis.

Survey Content

Achievement

Achievement in mathematics was assessed by tests in the following four areas:

- computation (items from the Stanford Achievement Test)
- algebra (items from the Cooperative Algebra I and Algebra II Tests)
- problem solving (items from the Metropolitan Achievement Tests)
- spatial visualization (items from the Revised Minnesota Paper Form Board)

Participation

For the purposes of the survey, participation was defined using the most advanced mathematics course a student took during high school. Four levels were used:

- General Mathematics and/or Algebra I
- Algebra II and/or Geometry
- Trigonometry and/or Probability and Statistics
- Pre-Calculus and/or Calculus

For the twelfth grade sample, mathematics participation was determined by asking respondents to indicate which of twelve mathematics courses they had taken. Courses ranged from General, Business or Consumer Mathematics to Pre-Calculus and Calculus. Each student was categorized into one of the four participation levels listed above based upon the level at which he or she terminated his or her mathematics course work.

To measure *intended participation* for 13-year-olds, the survey asked 13-year-olds to indicate the number of years of mathematics they planned to take during four years of high school.

Students were also asked if they took (for the grade 12 sample) or if they were presently taking (for the 13-year-old sample) algebra while in eighth grade. This variable was included since algebra in the eighth grade could represent "fast tracking" in mathematics. A differential enrollment for the sexes at this early point in their mathematics careers might be a starting point for the disparity in course-taking for males and females.

Sex-Role Stereotyping

Sex-role stereotyping influences included three variables. The first, *general sex-role stereotyping*, addressed the effects of traditional sex-roles on a female's view of mathematics. Students with "traditional" views about sex-roles might be less likely to view mathematics as useful to their future. The second variable measured the student's perception of *mathematics as a male domain*. The third variable looked at *men's attitudes toward women who are successful in mathematics*. Scores on this item provided an indication of the level of women's concern for male attitudes and how that concern might affect mathematics course-taking for women.

Career and Academic Plans

Students were asked to choose *the career that they planned to have* from a list of eight groups of careers. They were then asked how *much mathematics was necessary for that career*. Finally, they were asked to rate the importance of a list of *factors which might have affected their decision* about pursuing a particular career.

Two items were included in *academic plans*. The first was *academic aspirations* — that is, the highest level of education the student expected to complete. The second variable measured the importance of nine different *factors affecting the students' course-taking decisions*.

Attitudes Toward Mathematics

The students' attitudes toward mathematics were divided into two categories:

- mathematics and oneself
- usefulness of mathematics

Mathematics and oneself included three variables:

- enjoyment of mathematics
- confidence in mathematics
- anxiety in mathematics

Two components of usefulness were addressed — usefulness of mathematics in daily life and usefulness to career and educational plans.

Parental Influence

Parental influence can strongly affect a student's course-taking, achievement in mathematics and career aspirations through role modeling, direct encouragement and expression of attitudes toward mathematics. Variables in the area of parental influence measured the student's perceptions of the attitudes, behaviors and abilities of parents.

The first variable in this area was that of the *role model of the parents*, which measured the parents' passive influence, or the results of the examples set by the parents. Next was *parents' encouragement in mathematics*, a measure of the active encouragement given by the mother and/or father. Even if a parent has very limited ability in mathematics, he or she could still have a strong positive influence through direct encouragement. *Parents' stereotyping of mathematics* measured whether or not the student believed his or her parents thought mathematics is "more for males than for females." The next variable determined *which parent helped with homework*, followed by the variable which measured *who used more mathematics*, mother or father.

Parents' educational expectations for offspring indicated the highest level of education that each parent expected the student to complete.

Influence of Others

The influence of significant other people in the students' life was gauged by seven scales or items. The first was that of *peer influence*. This variable dealt with what the students' friends think about people who are "good" in mathematics. The second, *peer stereotyping of mathematics*, measured whether or not the students' friends think that mathematics is more for males than for females. The next two variables measured *teacher encouragement in mathematics* and *counselor encouragement to take more mathematics*. The next two variables determined the extent of *teacher stereotyping of mathematics* and *teacher differential treatment* (does the teacher behave differently toward male and female students?). The last variable in this area, *sibling role models*, noted whether or not the student had an older brother or sister who was good in mathematics.

Background Variables

This group of influences was divided into four categories:

- age or grade of each student
- socioeconomic status
- parents' education
- parents' occupation

RESULTS

Three sets of results will be reported in this section: first, the results from the analysis of the mathematics achievement and participation data; second, the relationships (correlations) between students' attitudes and achievement or participation in mathematics; and finally, the results from a predictive model of students' achievement and participation in mathematics. The predictive model was produced by applying regression analyses to the survey data.

Sex Differences in Achievement

Figure 1 illustrates the achievement data for high school seniors and for 13-year-olds. The pattern of results found for the high school seniors and 13-year-olds on achievement subtests is similar to trends reported in previous surveys. Sex differences in achievement for the twelfth grade sample favored males on all four subtests, but the only statistically significant difference was on the problem-solving test. Males scored approximately seven percentage points higher on the problem-solving test. There were no significant sex differences on the spatial visualization measure.

For the 13-year-olds, females outperformed males on the computation subtest, a finding which agrees with earlier research. Females were evenly matched with males on problem-solving ability, but surpassed their male counterparts on the spatial visualization test by five percentage points.

For comparison, Figure 2 shows the results from the second mathematics assessment, which was conducted in 1977-78 by the National Assessment of Education Progress (NAEP). This assessment used a large national sample of 9-, 13- and 17-year-olds. Summary results of exercise sets on computation, algebra and application are reported for approximately 24,000 13-year-olds and 24,000 17-year-olds. Although these exercise sets were developed to measure the same mathematical skills, they are not the identical items which appeared in the standardized tests chosen for the Women in Mathematics study. Another difference is that students in the older group in the present Women in Mathematics study were in grade 12. Seventy-two percent of the 17-year-olds were in grade 11 and only about 14 percent in grade 12 in the NAEP study. Results from the NAEP second mathematics assessment are reported here because they are current, represent a very large national probability sample and substantiate the pattern of sex differences in achievement found in this study.

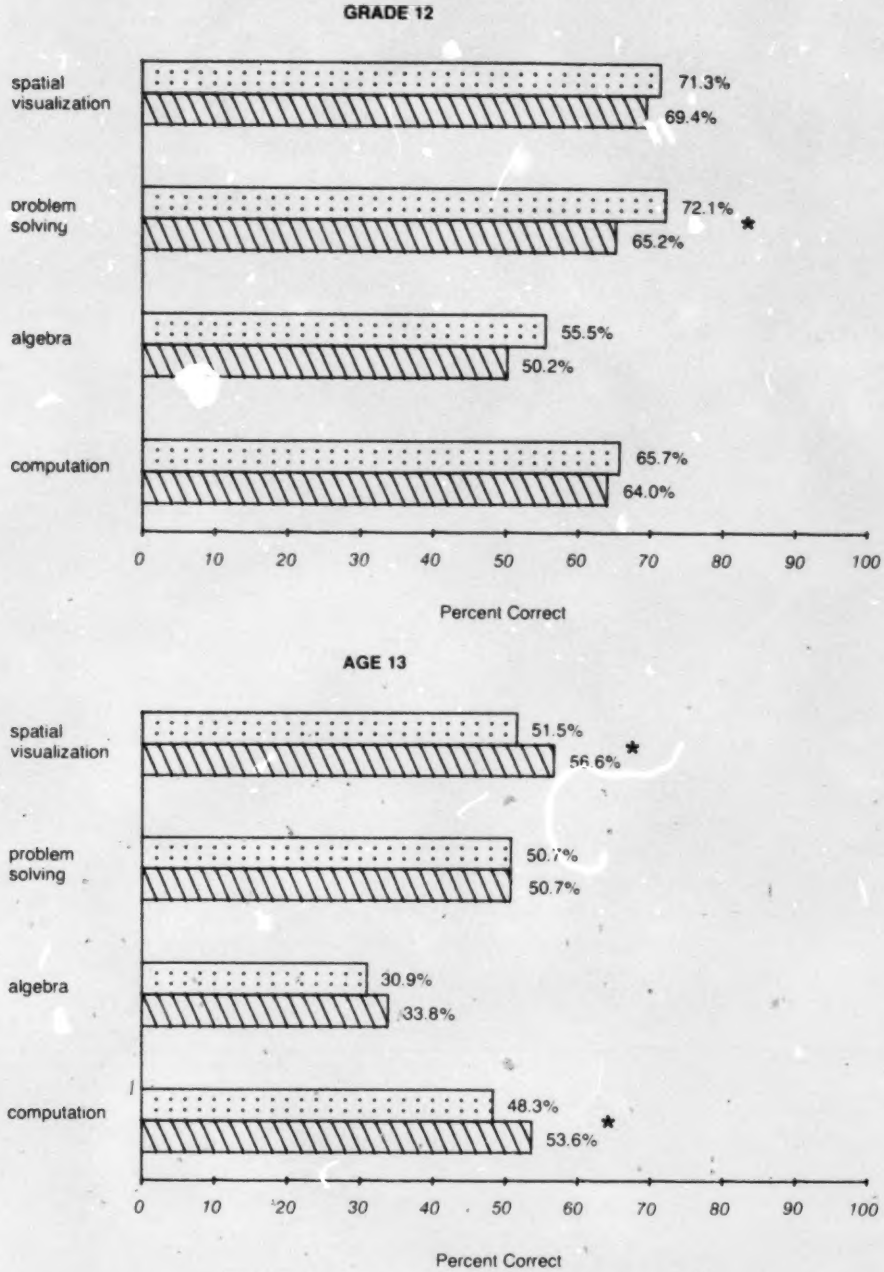
The results for 17-year-olds on comparable measures from the NAEP second mathematics assessment are similar to the results for the present study. No significant sex-related differences existed for computation or algebra, but a large and statistically significant difference of five percentage points favored males on the application (problem-solving) exercise set. Again, 13-year-old females did significantly better than males on computation items. One difference in results between the two surveys is that 13-year-old males outscored females by one and a half percentage points on problem-solving skills in the larger NAEP assessment.

Results from the two surveys indicate the same general pattern of performance for the two sexes and two ages. Females enter high school with approximately the same mathematical understanding and skills as the males. Sometime during the high school years, males catch up with and then surpass the females in certain areas of mathematics achievement. Is this phenomenon easily explained by the notion that males take more mathematics while in high school and thus have higher achievement scores? Some insight into this hypothesis can be obtained by looking at high school mathematics participation for both males and females.

Sex Differences in Participation

Figure 3 shows percentages of students in grade 12 who indicated that they had completed, or were presently taking, each of twelve high school mathematics courses. Few sex differences in mathematics partici-

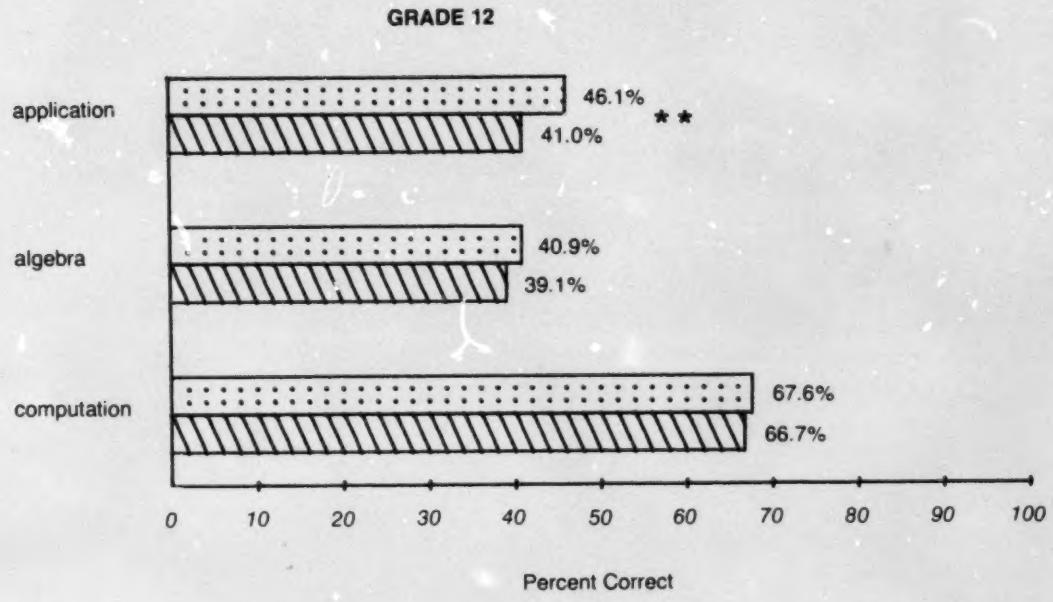
FIGURE 1. Mathematics Achievement From the Women in Mathematics Survey, Fall, 1978. Percentages of Correct Responses by Age and Sex

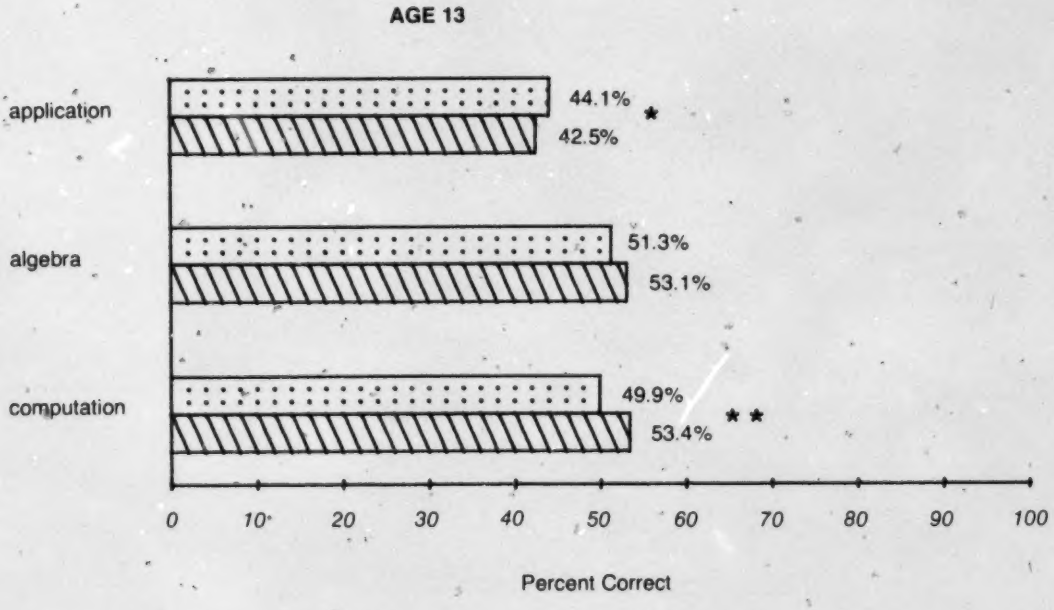


*difference is statistically significant at .05 level

Key: Males, Females

FIGURE 2. Mathematics Achievement From the NAEP Second Mathematics Assessment, 1977-78. Percentages of Correct Responses by Age and Sex

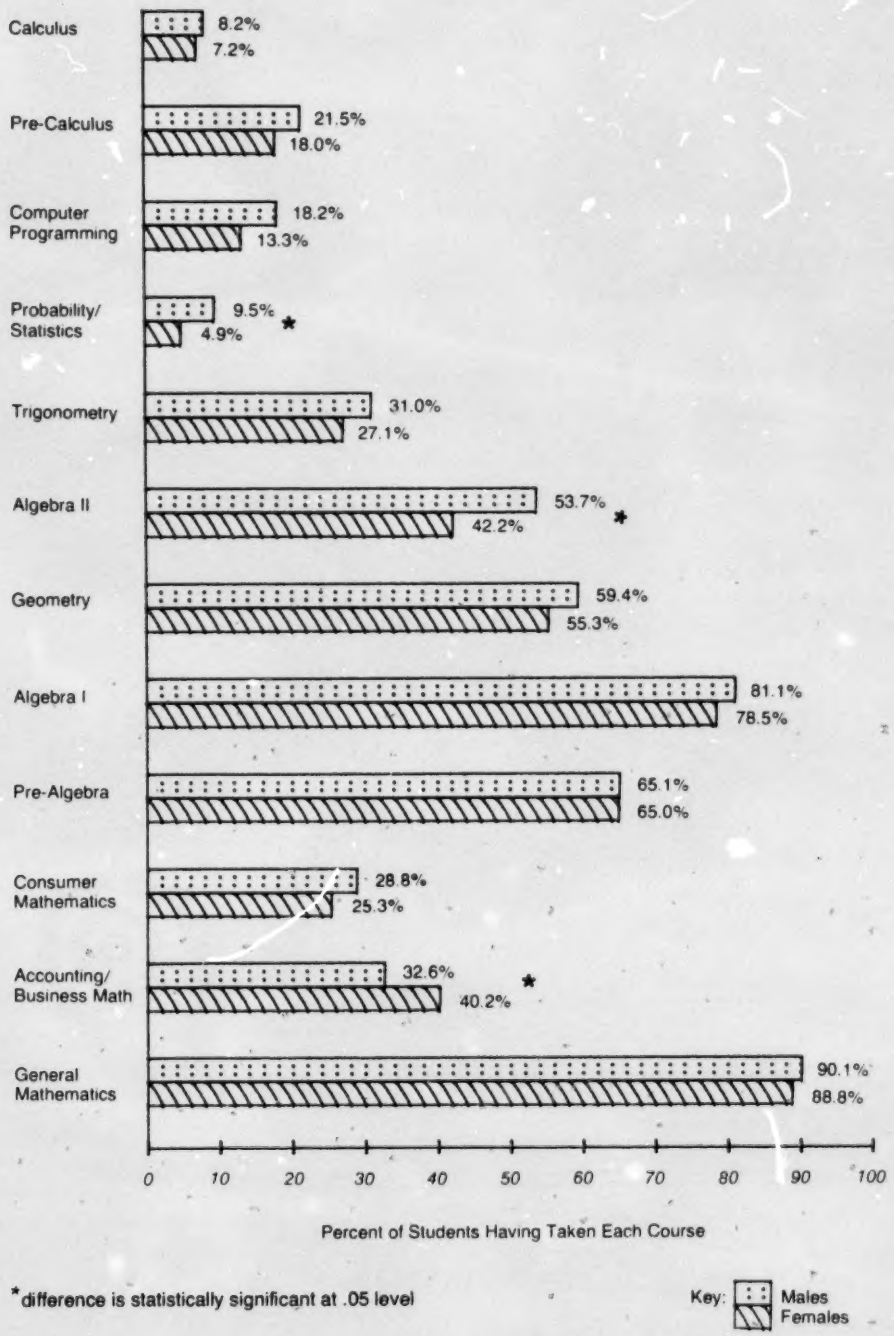




*difference is statistically significant at .05 level
**difference is statistically significant at .01 level

Key: Males, Females

FIGURE 3. Mathematics Participation of Grade 12 Students From the Women in Mathematics Survey, Fall, 1978. Percentages of Students by Sex Presently Taking or Having Completed Each Course



pation were found for the lower-level high school mathematics courses; in fact, only three of the twelve courses showed significant sex differences in enrollment. Significantly more females took Business or Accounting Mathematics while significantly more males took Algebra II and Probability/Statistics. Almost four percent more males took Trigonometry; five percent more took Computer Programming and three percent more took Calculus. None of these differences, however, were statistically significant.

Enrollment statistics for 17-year-olds are reported for the NAEP second mathematics assessment in Figure 4. Since most of these students were in the eleventh grade, they had not had the opportunity to take as much mathematics as the students reported on in Figure 3. Thus, the total percent for course enrollments is somewhat lower. The trends in participation are similar, but some interesting differences appear.

Significant sex-related differences in enrollments were found for the higher-level mathematics courses of Trigonometry and Pre-Calculus/Calculus. Although only 3.6 percent more males took Trigonometry, this percentage difference represents a 55-45 percent male-female enrollment split in the classroom. Similarly, the fact that only 1.8 percent more men took either Pre-Calculus or Calculus can be somewhat deceiving since this represents almost a 3:2 ratio of men to women in these higher-level courses. Fully 60 percent of the students in Pre-Calculus/Calculus are men and only 40 percent are women, according to the NAEP survey. The finding that 3.5 percent more males than females took Pre-Calculus in the Women in Mathematics study may reflect a reliable difference which might have been significant if a larger and statistically more powerful sample had been drawn.

For 13-year-olds, the reported number of years that they intended to take mathematics in high school is shown in Figure 5. It is important to remember that the results are an intended rather than an actual participation measure; therefore, it may not be as valid a measure as that for the grade 12 sample. More males than females intended to take one year of high school mathematics, but approximately the same number of females as males intended to take two, three or four years of high school mathematics. Thus, no significant sex differences were found among 13-year-olds for intended participation in higher-level mathematics courses.

The results suggest that the widely disparate sex differences in participation found in earlier small-scale studies (Sells, 1973; Ernest, 1976) are diminishing. The pattern for both the NAEP and the present survey indicate that participation for males and females is similar for the basic mathematics courses, while some differences in mathematics enrollment favor males at the higher-level courses.

The participation results raise the question as to whether the few sex differences in mathematics participation are large enough to account for the observed sex differences in achievement. To investigate any possible effect of participation on achievement, achievement scores were tabulated within levels of participation.

Sex Differences in Achievement Within Participation Levels

Scores on the four achievement subtests are shown in Table 1 for males and females in grade 12 within seven different participation levels. These levels were defined by the highest mathematics course taken when in high school and can be thought of as the stopping point in a student's mathematics education. Achievement subtest scores, sample size, standard errors, the difference in scores between sexes and the standard error of the difference are given for each level of participation.

No statistically significant sex-related differences existed on the computation or algebra achievement tests at any level of participation. Differences did appear in favor of males on the problem-solving measure in four of the seven participation levels. However, no significant difference in achievement appeared at the two highest levels of participation.

For spatial visualization, a significant sex difference was found only at the lowest level of participation where males scored higher than females on the spatial test.

The NAEP sample of 17-year-olds also showed sex differences in achievement within levels of mathematics participation. The results are presented in Table 2 and indicate persistent sex differences favoring males at every level of participation on the application (problem-solving) set of items. The increase in the size of the sex difference as the level of mathematics participation increases is striking.

FIGURE 4. Mathematics Participation of 17-Year-Old Students From the NAEP Second Mathematics Assessment, Spring, 1978. Percentages of Students by Sex Who Have Studied Each Course

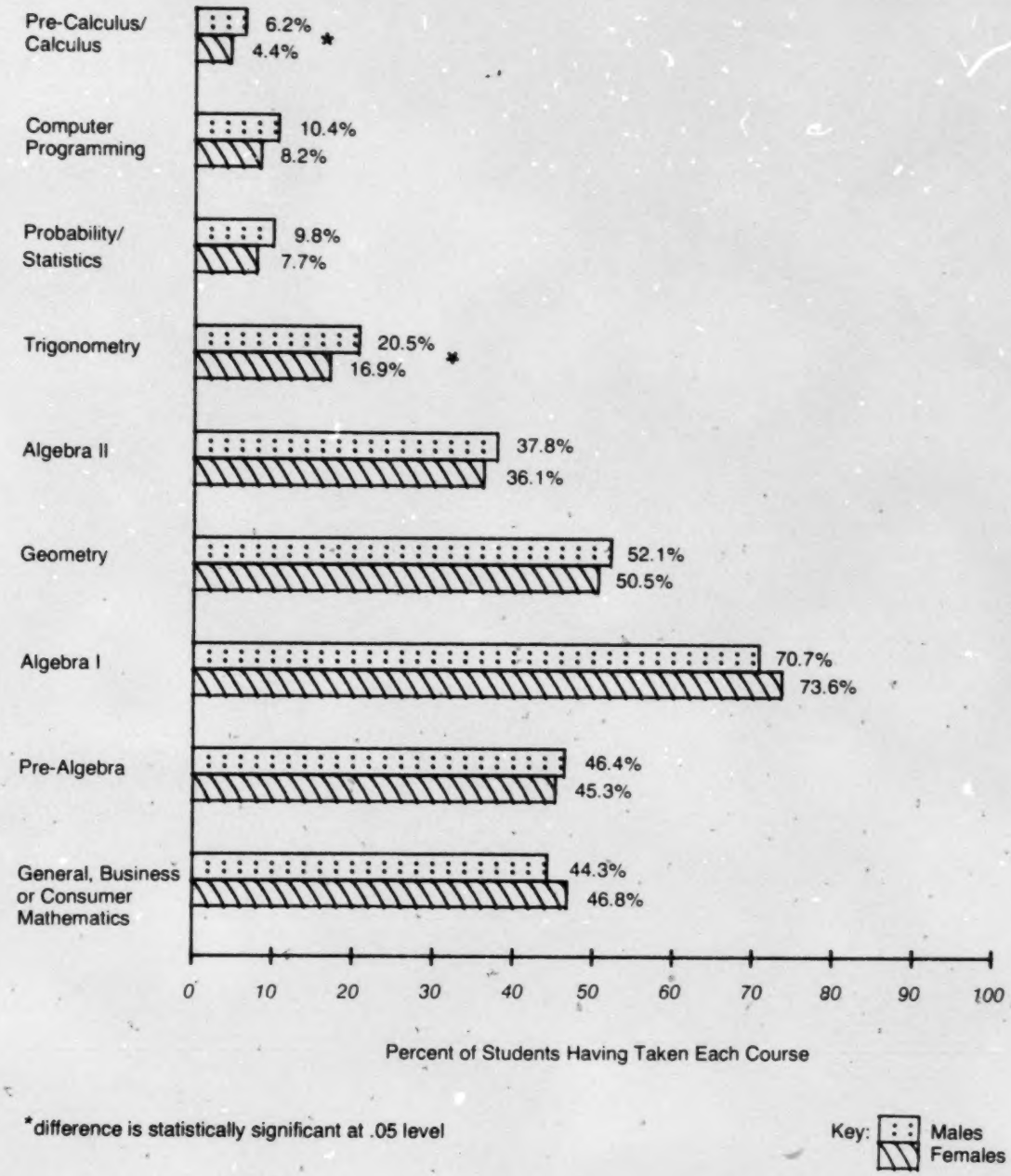
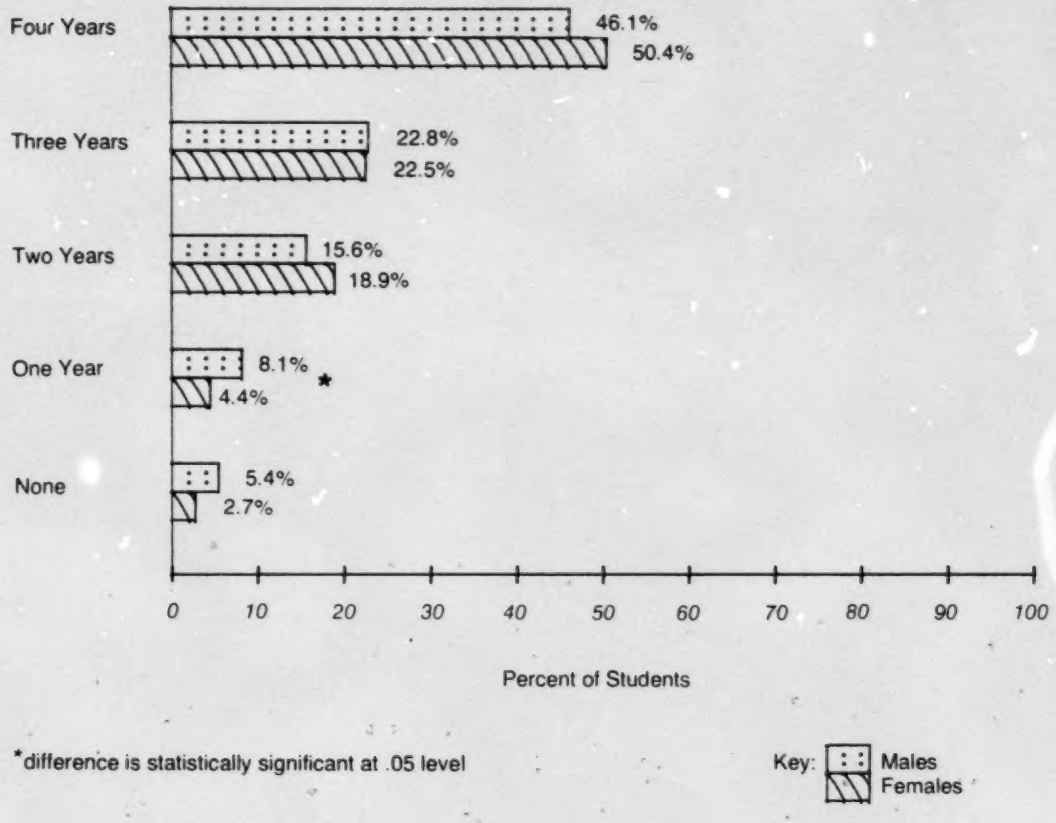


FIGURE 5. Intended Mathematics Participation for 13-Year-Old Students From the Women in Mathematics National Survey, Fall, 1978. Percentages of Students by Sex Who Intend To Take High School Mathematics Courses



*difference is statistically significant at .05 level

Key: Males, Females

TABLE 1. Mathematics Achievement Within Participation Level for Grade 12 Students From the Women in Mathematics National Survey, Fall, 1978. Percentages of Correct Response by Sex

Level of Participation		Male	Female	Difference	Male	Female	Difference
			Computation			Algebra	
General Math, Business Math, Consumer Math, Pre-Algebra	%	47.50	48.05	-.55	31.23	25.40	5.83
	S.E. †	1.97	2.53	3.20	1.51	2.68	3.08
	n §	116	119		95	109	
Algebra I	%	56.21	58.05	-1.84	32.39	35.73	-3.34
	S.E.	2.30	2.50	3.40	2.13	1.50	2.61
	n	114	145		108	142	
Geometry	%	60.59	63.09	-2.50	46.37	44.90	1.47
	S.E.	3.38	2.72	4.34	5.42	2.95	6.17
	n	55	101		54	99	
Algebra II	%	70.87	67.04	3.83	64.50	57.20	7.30
	S.E.	1.58	3.51	3.85	2.71	3.61	4.51
	n	113	122		133	121	
Trigonometry and/or Probability/Statistics	%	70.40	68.34	2.06	60.32	64.89	-4.57
	S.E.	2.89	2.58	3.87	2.87	2.54	3.83
	n	161	167		157	165	
Pre-Calculus	%	77.78	76.76	1.02	75.04	70.30	4.74
	S.E.	1.81	2.17	2.83	2.14	3.18	3.83
	n	192	175		191	175	
Calculus	%	80.59	86.21	-5.62	80.85	83.10	-2.25
	S.E.	2.57	1.68	3.07	2.72	2.34	3.59
	n	110	84		109	83	
			Problem Solving			Spatial Visualization	
General Math, Business Math, Consumer Math, Pre-Algebra	%	58.49	51.20	7.29*	63.77	56.89	6.88*
	S.E.	2.16	2.59	3.36	2.55	1.50	2.96
	n	115	121		111	117	
Algebra I	%	66.11	60.10	6.01*	68.15	65.31	2.84
	S.E.	2.10	1.94	2.86	4.91	1.94	5.28
	n	115	145		109	142	
Geometry	%	68.36	66.15	2.21	66.08	73.71	-7.63
	S.E.	3.26	1.82	3.73	3.09	2.33	3.87
	n	55	102		51	99	
Algebra II	%	76.27	64.39	11.88*	72.56	69.90	2.66
	S.E.	2.01	2.88	3.51	2.63	2.77	3.82
	n	113	122		111	115	
Trigonometry and/or Probability/Statistics	%	73.52	67.23	6.29*	71.35	74.23	-2.88
	S.E.	1.91	1.77	2.60	2.46	1.78	3.04
	n	162	167		154	160	
Pre-Calculus	%	81.87	79.68	2.19	79.64	77.29	2.35
	S.E.	1.58	2.60	3.04	1.27	2.75	3.03
	n	190	175		186	166	
Calculus	%	86.49	85.52	.97	78.34	79.96	-1.62
	S.E.	2.79	1.98	3.42	2.42	2.15	3.24
	n	109	84		107	82	

* difference is statistically significant at .05 level
† S.E. is the standard error
§ n is the sample size

TABLE 2. Mathematics Achievement Within Participation Levels for 17-Year-Old Students From the NAEP Second Mathematics Assessment, Spring, 1978. Percentages of Correct Responses by Sex

Level of Participation		Objective: Computation (127 Items)			Objective: Algebra (59 Items)			Objective: Application (136 Items)		
		Male	Female	Difference	Male	Female	Difference	Male	Female	Difference
General Mathematics	%	47.03	48.32	-1.29	22.79	21.96	.83	30.39	27.95	2.44**
	S.E. †	.82	.83	1.16	.36	.44	.57	.48	.37	.61
	n §	2,500	2,534		2,501	2,536		2,500	2,534	
Algebra I	%	62.25	61.51	.74	31.44	30.33	1.11	38.93	34.53	4.40**
	S.E.	.90	.76	1.17	.64	.55	.85	.72	.61	.94
	n	1,631	2,176		1,629	2,179		1,632	2,176	
Geometry	%	70.66	69.35	1.31	37.93	37.62	.31	48.07	43.53	4.54**
	S.E.	.78	.75	1.13	.75	.65	.99	.70	.52	.87
	n	1,588	1,920		1,588	1,920		1,587	1,919	
Algebra II	%	80.44	78.08	2.36**	52.83	52.18	.65	55.06	48.73	6.33**
	S.E.	.69	.59	.90	.91	.75	1.08	.74	.65	.97
	n	2,619	2,890		2,618	2,892		2,617	2,891	
Higher Course than Algebra I	%	88.27	86.41	1.86*	69.02	65.56	3.46*	67.69	60.29	7.40**
	S.E.	.55	.58	.80	1.05	1.19	1.58	.66	.94	1.15
	n	1,539	1,139		1,539	1,139		1,539	1,139	

* difference is statistically significant at .05 level
** difference is statistically significant at .01 level
† S.E. is the standard error
§ n is the sample size

Interpreting these results is difficult. Based on the achievement scores for 13-year-olds, women start out in high school mathematics on a par with men. For most participation groups, women do as well as men on tests measuring the skills of computation and algebra. But, even when differences in participation are taken into account, men at nearly every level of participation have an advantage in solving typical one- and two-step textbook word problems.

Figures 1-5 and Tables 1 and 2 have presented data on the national picture of achievement and participation in mathematics for male and female 13-year-olds and high school seniors. Given that there are some significant sex differences in participation, what factors affect students' decisions to take more mathematics?

Relative Importance of Certain Factors Affecting the Decision To Take More Mathematics

Students were directly asked to rate the importance of each of nine factors which might have affected their decision to take more mathematics. The results were rank ordered and are shown in Table 3.

In grade 12, males and females selected nearly the same factors as important in deciding whether or not to take more mathematics. Both sexes indicated that the usefulness of mathematics was the most important factor, followed by confidence in and enjoyment of mathematics. While the influence of parents, teachers and counselors was thought to be moderately important, peer influence was not.

Thirteen-year-old females ranked the importance of the nine factors in the same order as males. Like high school seniors, 13-year-olds considered usefulness of mathematics to be most important and peer influence to be least important. Parents and teachers, however, had a stronger influence on the thirteen-year-olds.

The results in Table 3 are useful in two respects. First, by rank-ordering the results, the relative importance of the factors affecting the decision to take more mathematics is determined. And, even more significantly, the results give the student's direct indications as to which factors have the most potential for inclusion in future programs to increase participation.

TABLE 3. Rank Ordered Results on the Relative Importance of Certain Factors Affecting Students' Decisions To Take More Mathematics

Factors	Mean	Rank Order	Mean	Rank Order
	Grade 12 Females		Grade 12 Males	
1. How useful mathematics will be	80.91	1	79.27	1
2. How good or bad in mathematics	74.55	2	68.81	3
3. How much math is liked or disliked	72.43	3	69.20	2
4. What math teachers think	66.40	4	64.63	4
5. What mother thinks	65.73	5	63.03	6
6. What father thinks	62.51	6	64.19	5
7. What school counselor thinks	56.27	7	55.69	7
8. Whether friends take mathematics	25.12	8	31.83	8
9. Whether classmates approve	16.48	9	24.89	9
	Age 13 Females		Age 13 Males	
1. How useful mathematics will be	88.15	1	82.54	1
2. What mother thinks	79.40	2	77.12	2
3. What father thinks	77.41	3	76.45	3
4. What math teachers think	76.38	4	73.57	4
5. How good or bad in mathematics	72.87	5	69.47	5
6. How much math is liked or disliked	72.62	6	67.98	6
7. What school counselor thinks	63.86	7	62.06	7
8. Whether friends take mathematics	45.43	8	43.72	8
9. Whether classmates approve	35.05	9	42.21	9

Correlations of Study Variables With Participation

While reporting the sex differences for each variable included in the study would be interesting, it is more important to examine the correlation between each variable and participation or achievement. Correlations indicate the relationship between a variable and participation or achievement — sex differences, *per se*, do not.

Table 4 shows the correlations of the study variables with participation for both males and females in grade 12 and at age 13. Most correlations with participation are positive because all variables were scored in the direction of their contribution to a positive influence on participation (or achievement). For example, a high score on a stereotyping item indicated a "contemporary" attitude, that is, *no* stereotyping. Thus, a high correlation of mathematics as a male domain with participation indicated that those students who did *not* view mathematics as a subject only for males tended to take more mathematics. The same is true of the anxiety measures. A high score indicates *low* anxiety.

TABLE 4. Correlations Between Study Variables and Mathematics Participation for Grade 12 Students and 13-Year-Olds From the Women in Mathematics National Survey, Fall, 1978

Variables	Grade 12		Age 13	
	Male	Female	Male	Female
I. Sex-Role Stereotyping				
A. General Sex-Role Stereotyping	.074	.110	.182**	.060
B. Mathematics as a Male Domain	.099	.188**	.179**	.095
C. Men's Attitudes Toward Successful Women	.076	.081	.141*	.084
II. Career Plans				
A. Career Aspirations	.286**	.298**	.154*	.039
B. Mathematics Preparation Required for a Job	.499**	.400**	.193**	.103
C. Job Using Mathematics	.298**	.216**	-.116	-.142*
D. Job Done by Members of Opposite Sex	-.079	.014	.031	.008
III. Mathematics and Oneself				
A. Confidence in Mathematics	.466**	.423**	.280**	.194**
B. Anxiety in Mathematics	.348**	.325**	.285**	.192**
C. Anxiety in English	.109	.096	.015	.072
D. Anxiety in School	.212**	.225**	.272**	.092
E. Enjoyment of Mathematics	.472**	.375**	.284**	.264**
F. Locus of Control	.067	.046	.059	.097
IV. Usefulness of Mathematics	.341**	.301**	.378**	.256**
V. Academic Plans				
A. Educational Aspirations	.475**	.452**	.267**	.167**
VI. Parental Influences				
A. Father as a Role Model	.161**	.116**	.168**	.096
B. Mother as a Role Model	-.124*	-.032	.153*	.117
C. Father's Encouragement in Mathematics	.304**	.320**	.252**	.132
D. Mother's Encouragement in Mathematics	.340**	.305**	.276**	.177**
E. Father's Stereotyping of Mathematics	.050	.105	-.087	-.022
F. Mother's Stereotyping of Mathematics	.029	.100	-.083	-.065
G. Father's Educational Expectations	.466**	.386**	.207**	.104
H. Mother's Educational Expectations	.451**	.361**	.240**	.095

(This table is continued on the next page)

TABLE 4 (Cont.)

Variables	Grade 12 Male	Grade 12 Female	Age 13 Male	Age 13 Female
VII. Influences of Significant Others				
A. Peer Influence	.209**	.207**	.243**	.137*
B. Boys' Stereotyping of Mathematics	-.121	.028	-.063	-.001
C. Girls' Stereotyping of Mathematics	-.004	.085	-.057	-.037
D. Counselor Encouragement	.279**	.238**	.118	.240**
E. Teacher Encouragement	.414**	.433**	.243**	.161*
F. Teacher Stereotyping of Mathematics	.102	.104	.054	.024
G. Teacher Differential Treatment	.196**	.089	.149*	.059
H. Brother as Role Model	.077	.147*	.025	-.021
I. Sister as Role Model	.114	.099	.071	.010
VIII. School Experience				
A. Grades in Mathematics	.453**	.440**	.223**	.246**
B. Taking Algebra in 8th Grade	.344**	.256**	.002	.084
IX. Achievement				
A. Computation	.451**	.440**	.232**	.112
B. Algebra	.610**	.648**	.154**	.102
C. Problem Solving	.397**	.447**	.205**	.091
D. Spatial Visualization	.21****	.306**	.099	.086
X. Background Variables				
A. Father's Education	.25****	.329**	-.003	-.049
B. Mother's Education	.16****	.237**	.032	-.016
C. Socioeconomic Status	.12**	.181**	.136	.005
D. Father's Occupation	.149	.257**	-.015	.016
E. Mother's Occupation	.153*	.136*	.023	.087

* difference is statistically significant at .01 level
** difference is statistically significant at .001 level

Grade 12 Sample

For high school seniors, career and education plans were positively related to mathematics participation. The chosen career, the student's perception of the necessity of using mathematics and the amount of mathematics required for a job were all highly correlated with course-taking. Students' education aspirations were significantly related to taking high school mathematics. Those students who planned to continue their education through college and graduate school were more likely to have taken more advanced mathematics than those students who had lower academic aspirations.

A second category of variables, positive feelings toward mathematics and one's ability in mathematics, showed a strong positive relationship with mathematics course-taking. A positive attitude toward mathematics, indicated by confidence in mathematics, low anxiety and enjoyment of mathematics, was highly correlated with participation. Students who liked mathematics and believed they were good in it tended to take more mathematics while in high school than students with poorer attitudes.

The variables of parental, teacher, peer and counselor encouragement, a third category of variables, also affected participation in mathematics. Fathers (but not mothers) as role models and the active encouragement of both mothers and fathers were significantly correlated with participation for both males and females. Another form of parental encouragement was parents having high academic expectations for their children. Those students, especially males, whose parents had high academic expectations for them took more mathematics.

Students who perceived their teachers as encouraging tended to take more mathematics. Teacher

differential treatment was one of the few variables for high school seniors which was significantly correlated with course-taking for males, but not for females. Males who perceived mathematics teachers as treating males the same as females tended to take more mathematics.

Counselor encouragement seemed to have an effect on course-taking for most students. Only those students who indicated they had been counseled (59 percent of the grade 12 sample) were included in this correlational analysis. Both male and female students who indicated they had a counselor who encouraged them to take mathematics were more likely to have taken mathematics.

Approval, support and encouragement of peers may contribute to mathematics participation. Although not as highly correlated as other variables, peer influence did have a low but significant correlation with taking high school mathematics.

For females, having an older brother who was good in mathematics was related to taking more mathematics. This was not true for either males or females having an older sister who was good in mathematics. This is not surprising since males have traditionally taken more mathematics so it would be more likely to have an older brother, rather than an older sister, who was good in mathematics.

Correlations of participation with achievement were among the highest correlations found. This is not an unexpected result, especially when the correlation with algebra is examined. This is the one subtest which was probably the most course-dependent. That is, a student would have had to have a course in algebra to do well on this subtest. This idea is substantiated by the highest correlation of algebra with participation of all the achievement subtests. In general, high correlations of achievement subtests with participation indicated that taking more mathematics was highly related to better performance on achievement measures.

Numerous background variables were related to mathematics participation for both males and females. A student's typical letter grade in mathematics was highly correlated with participation as was taking Algebra I in the eighth grade. This latter variable is probably a surrogate for other factors such as high achievement in mathematics in the elementary school, size of the school and a well-developed mathematics program.

Socioeconomic status (SES) showed a low but significant correlation with participation for females but not for males. But, components of SES — parents' education and occupation — were significantly correlated with course-taking for both sexes.

While the above positive correlations of variables with participation are important, it is also significant that some of the "causal variables" identified in earlier studies were not correlated. In general, most of the stereotyping measures were not significantly correlated with participation (for example, stereotyping of sex-roles or parent, teacher and peer stereotyping of mathematics as a male domain).

One interesting exception to the lack of significant correlations with stereotyping measures is the result for twelfth grade women on the mathematics as a male domain scale. The women who did pursue advanced mathematics courses tended not to sex-type mathematics as a subject appropriate only for men.

Thirteen-Year-Old Sample

The basic categories of variables which correlated with participation for the high school seniors were similar, although not identical, to those for 13-year-olds. The participation variable for 13-year-olds was based on the item which asked how much mathematics they intended to take while in high school; it was not a measure of actual participation.

Educational aspirations, a positive feeling toward mathematics and the influence of parents, peers and teachers were related to participation for 13-year-olds, as they were for high school seniors.

Thirteen-year-old males seemed to be influenced more by their fathers than their mothers; the reverse was true for 13-year-old females. Parents as role models and parental encouragement were related to intended mathematics participation for males, but the only similar significant parental influence for females was mothers' encouragement. Interestingly, fathers' and mothers' educational expectations were correlated with intended participation only for males and not females, even though 13-year-old females per-

ceived their parents as having higher educational expectations for them than did 13-year-old males. As was found for twelfth grade students, peer influence and teacher encouragement were related to intended participation for 13-year-olds. Counselor encouragement was related only for females.

Fewer background variables were correlated with participation. Socioeconomic status and parents' occupation and education were not correlated for 13-year-olds as they were for seniors, probably because 13-year-olds were unsure of and, therefore not as accurate in reporting, the parents' education and occupation.

Grades in mathematics were related to intended course-taking for both sexes, but achievement in mathematics as measured by the subtests were correlated for males but not for females.

In summary, the information gained from the correlational analyses indicated that many of the variables may be "operating" in the same way for males and females, especially for the older group. The variables which correlated with participation were those related to career and future educational aspirations, perceived usefulness of mathematics, liking mathematics and being good in it, and the active approval and encouragement of taking more mathematics by parents, teachers, counselors, and to some degree, peers.

Correlations of Study Variables With Achievement

Table 5 shows the results of correlational analyses for mathematics achievement. Since participation is a likely predictor of achievement, it is not surprising that many of the variables which correlated with participation also correlated with achievement. Career plans, mathematics required for the chosen career, liking of mathematics, usefulness of mathematics, parental encouragement, parental educational expectations, peer and teacher influence and socioeconomic status were significantly correlated with achievement for the grade 12 sample. Mathematics as a male domain was correlated with achievement for both males and females in grade 12. Absence of stereotyping women who are successful in mathematics was related to achievement only for women.

When 13-year-olds were compared with high school seniors, stereotyping proved to be a much bigger issue for the younger age group. Females who did not accept traditional sex-role stereotypes (e.g., they did not feel that mathematics is a male domain or did not think that men hold negative attitudes toward women who are successful in mathematics) tended to have higher achievement scores. Another interesting difference was that 13-year-olds who did well in mathematics did *not* perceive the parents (either father or mother) as being encouraging. Also, neither the mathematics preparation required for a job nor the fact that a job required mathematics correlated with achievement for the 13-year-olds, although they did for the seniors.

In summary, many of the variables which correlated with participation also correlated with achievement. After examining these correlations, it is easy to understand why so many previous studies looked at so many different variables which might affect participation and achievement. Many of the variables included in earlier studies were shown to be significantly related to course-taking by the present survey.

Given the correlations just discussed, the obvious question is: Which of the factors that correlated with participation or achievement are the best predictors? To address this question, the correlation matrix of selected variables was incorporated into a predictive model to gain more insight into the importance of individual factors in predicting participation or achievement in mathematics.

Predictive Analyses

For this study, a purely predictive model, rather than a causal model was used. Predictive models have the advantage of requiring few assumptions about the causal connections between predictors. Causal models, such as the technique of path analysis, require numerous *a priori* assumptions, resulting in many possible causal models. For these reasons, regression, a more conservative predictive technique, was used.

Factor analysis was used to reduce the study variables to a smaller set of relatively independent factors composed of scales. Even after the survey items were subjected to factor analysis, a fairly diffuse pattern of correlations between factors remained. This poses a problem in regression analysis since a step-wise hierarchical design is used. For example, if two or

TABLE 5. Correlations Between Study Variables and Mathematics Achievement for Grade 12 Students and 13-Year-Olds From the Women in Mathematics National Survey, Fall, 1978

Variables	Grade 12		Age 13	
	Male	Female	Male	Female
I. Sex-Role Stereotyping				
A. General Sex-Role Stereotyping	.068	.075	.198**	.329**
B. Mathematics as a Male Domain	.209**	.313**	.267**	.451**
C. Men's Attitudes Toward Successful Women	.115	.137*	.176**	.318**
II. Career Plans				
A. Career Aspirations	.298**	.194**	.168*	.186*
B. Mathematics Preparation Required for a Job	.405**	.323**	.049	-.056
C. Job Using Mathematics	.291**	.174**	-.103	-.034
D. Job Done by Members of Opposite Sex	-.095	-.122*	.094	-.057
III. Mathematics and Oneself				
A. Confidence in Mathematics	.479**	.424**	.360**	.338**
B. Anxiety in Mathematics	.354**	.321**	.313**	.270**
C. Anxiety in English	.102	.066	.078	.239**
D. Anxiety in School	.283**	.198**	.256**	.273**
E. Enjoyment of Mathematics	.396**	.361**	.181**	.080
F. Locus of Control	.104	.075	.102	.038
IV. Usefulness of Mathematics	.292**	.255**	.295**	.200**
V. Academic Plans				
A. Educational Aspirations	.462**	.395**	.237**	.238**
VI. Parental Influences				
A. Father as a Role Model	.183**	.099	.161*	.157*
B. Mother as a Role Model	-.104	-.041	.026	-.054
C. Father's Encouragement in Mathematics	.316**	.320**	.130	.095
D. Mother's Encouragement in Mathematics	.298**	.256**	.124	.095
E. Father's Stereotyping of Mathematics	.066	.055	-.062	-.121
F. Mother's Stereotyping of Mathematics	.026	.074	-.083	-.132
G. Father's Educational Expectations	.501**	.325**	.216**	.198*
H. Mother's Educational Expectations	.505**	.228**	.190*	.161*

(This table is continued on the next page)

TABLE 5 (Cont.)

Variables	Grade 12 Male	Grade 12 Female	Age 13 Male	Age 13 Female
VII. Influences of Significant Others				
A. Peer Influence	.275**	.238**	.238**	.234**
B. Boys' Stereotyping of Mathematics	-.052	-.016	-.053	-.074
C. Girls' Stereotyping of Mathematics	.038	.127	-.196	-.219**
D. Counselor Encouragement	.202**	.258**	.256**	.195**
E. Teacher Encouragement	.380**	.360**	.238**	.188**
F. Teacher Stereotyping of Mathematics	.100	.084	.174*	.164*
G. Teacher Differential Treatment	.225**	.183**	.225**	.297**
H. Brother as Role Model	.131*	.158*	.095	.198*
I. Sister as Role Model	.237**	.110	.130	.125
VIII. School Experience				
A. Grades in Mathematics	.447**	.480**	.386**	.403**
B. Taking Algebra in 8th Grade	.160**	.216**	.309**	.373**
IX. Participation	.559**	.596**	.263**	.120
X. Background Variables				
A. Father's Education	.282**	.318**	-.060	-.073
B. Mother's Education	.272**	.286**	-.056	-.099
C. Socioeconomic Status	.167**	.258**	.150*	.186**
D. Father's Occupation	.237**	.197**	.030	.065
E. Mother's Occupation	.156*	.091	.002	.009

* difference is statistically significant at .01 level
** difference is statistically significant at .001 level

three variables are highly correlated with each other, the regression model might identify only the variable which is the strongest predictor of the three variables, leaving the other two unidentified.

To alleviate the problem of diffuse correlations, variables were sorted into one of three categories before they were entered into the regression analyses. First, they were classified as to whether they were "intervenable" through conventional means (e.g., through programs which may be initiated in the schools). Nonintervenable variables included school enrollment, availability of mathematics courses offered by the school and socioeconomic status (SES). The remainder of the scales were categorized as either representing "self" or "others" characteristics. "Self" characteristics were scales related to student attitudes toward mathematics and stereotyping. The "others" category included effects of parents, teachers and school counselors. Separate regression analyses were performed for each of the "self" and "others" variables. The nonintervenable variables were considered primary whenever achievement or participation were predicted by a confounded variation of intervenable and nonintervenable variables. Technically speaking, the predictive models were hierarchical designs which identified portions of residual variance in achievement or participation which were tied to variance in either "self" or "others" variables. Nonintervenable variables were entered simultaneously in the first step. The remainder of the variables were then entered in a step-wise fashion. In each step, the variable that was included was the one with the highest partial correlation with either achievement or participation. Although this method established an *a posteriori* sequence based upon the unique residual covariance in each step, the order of predictor variables should not be taken too literally because of the existence of some intercorrelations between variables. What should be noted is the increase in predicted variance over that which is possible from the nonintervenable factors.

Results of the regression analyses predicting

achievement are presented in Table 6. Analyses were done separately for each age and sex. Looking at Table 6, it can be seen that parental encouragement, the passive influence of mother as a role model and the parents' educational expectations accounted for an additional 28 percent of the variance for the twelfth grade males when "others" were used to predict achievement. In a second model in which student characteristics were used, attitudes toward mathematics, educational, and career aspirations and the perceived amount of mathematics needed for a job accounted for a 31 percent increase in total variance after the nonintervenable variables were accounted for. In these two models, "self" and "others" variables explained about 30 percent of the variances, making these fairly powerful predictive models.

Similar results were found for females in grade 12. In terms of "others," influences of parents and teachers seemed to be the best predictors of achievement. Teacher encouragement, father's educational expectations, parental encouragement, mother as a role model and counselor encouragement accounted for a 19 percent increase in explained variance. The second model predicting mathematics achievement for twelfth grade females considered student characteristics. A 26 percent increase in predicted variance was attributable to attitudes toward mathematics, educational aspirations and the amount of mathematics preparation needed for a job.

Considerably less variance could be determined based on the characteristics of "others" or "self" for 13-year-old males. Only 10 percent of the variance could be predicted by teacher differential treatment, father's educational expectations and counselor encouragement. Characteristics of the student predicted achievement better for 13-year-old males. Attitudes toward mathematics, the (lack of) stereotyping of women, educational aspirations and locus of control (the student perceiving himself as solely responsible for how well he does in mathematics) predicted an additional 16 percent of the variance.

Results on achievement regression analyses for 13-year-old females were similar to those for males. Again, teacher differential treatment, father's educational expectations and counselor encouragement were the variables related to "others" which best predicted achievement. Lack of stereotyping of women, attitudes toward mathematics, school anxiety and educational aspirations were the student characteristics which best predicted achievement.

Table 7 presents results of the regression analyses for mathematics participation. As was done for the analyses predicting achievement, nonintervenable variables of school characteristics were entered first and taken into account in the subsequent analyses.

For twelfth grade males, father's educational expectations, counselor encouragement, mother as a role model, mother's educational expectations and parental encouragement accounted for a 28 percent increase in explained variance. Attitudes toward mathematics and educational and career aspirations accounted for an additional 36 percent of the variance when only "self" variables were included in the analysis.

When the predictive models for achievement and participation are compared for males in grade 12, the results are remarkably similar. The identified variables for both predictive models were identical, but for achievement, teacher encouragement added to the predictive model of "others", and career aspirations added to the predictive model of "self".

For twelfth grade females, the variables related to "others" which were the best predictors of participation were father's educational expectations, teacher encouragement and (lack of) stereotyping. This variable accounted for an increase of 21 percent of the variance. The characteristics of "self" which were most predictive were educational aspirations, attitudes toward mathematics and the mathematics preparation required for a job. These accounted for 30 percent of the variance in this model after the variance attributed to the nonintervenable variables was accounted for.

Differences do exist for "others" variables, which predict participation when grade 12 males and females are compared. Father's educational expectations predicted participation for both groups, but teacher variables seemed to play a more important role in predicting female participation. Influences of parents and counselors appeared to be better predictors for males.

The lack of validity of the participation measure for 13-year-olds made it very difficult to accurately predict intended participation. This is reflected in the low

TABLE 6. Predictive Models for Mathematics Achievement Utilizing Student Attitudes or Parental and Teacher Characteristics*

Variable	Squared Multiple Correlation	"Intervenable" Variance R^2 Total—R^2 Nonintervenable
Grade 12 Males		
"Nonintervenable" Variables		
School Enrollment		
Socioeconomic Status		
Number of Mathematics Courses Offered		
Most Advanced Mathematics Course Offered	.06	.00
Predictive Model 1: Characteristics of Others		
Mothers Educational Expectations		
Teacher Encouragement		
Mother As a Role Model	.35	.28
Parental Encouragement		
Predictive Model 2: Characteristics of Self		
Attitudes Toward Mathematics		
Educational Aspirations		
Mathematics Preparation Required for Job	.38	.31
Career Aspirations		
Age 13 Males		
"Nonintervenable" Variables		
School Enrollment	.03	.00
Socioeconomic Status		
Predictive Model 1: Characteristics of Others		
Teacher Differential Treatment		
Fathers Educational Expectations	.13	.10
Counselor Encouragement		
Predictive Model 2: Characteristics of Self		
Attitudes Toward Mathematics		
Stereotyping of Women		
Educational Aspirations	.19	.16
Locus of Control		

*Only variables adding at least 1% to predicted variance are included.

Variable	Squared Multiple Correlation	"Intervenable" Variance R^2 Total—R^2 Nonintervenable
Grade 12 Females		
"Nonintervenable" Variables		
School Enrollment		
Number of Mathematics Courses Offered		
Socioeconomic Status		
Most Advanced Mathematics Course Offered	.12	.00
Predictive Model 1: Characteristics of Others		
Teacher Encouragement		
Fathers Educational Expectations		
Counselor Encouragement		
Parental Encouragement	.31	.19
Mother As a Role Model		
Predictive Model 2: Characteristics of Self		
Attitudes Toward Mathematics		
Educational Aspirations		
Mathematics Preparation Required for Job	.38	.26
Age 13 Females		
"Nonintervenable" Variables		
School Enrollment	.03	.00
Socioeconomic Status		
Predictive Model 1: Characteristics of Others		
Teacher Differential Treatment		
Counselor Encouragement		
Fathers Educational Expectations	.23	.20
Mother As a Role Model		
Predictive Model 2: Characteristics of Self		
Stereotyping of Women		
Attitudes Toward Mathematics	.26	.23
School Anxiety		
Educational Aspirations		

TABLE 7. Predictive Models for Mathematics Participation Utilizing Student Attitudes or Parental and Teacher Characteristics*

Variable	Squared Multiple Correlation	"Intervenable" Variance R^2 Total—R^2 Nonintervenable
Grade 12 Males		
"Nonintervenable" Variables		
School Enrollment		
Socioeconomic Status		
Number of Mathematics Courses Offered	.03	.00
Most Advanced Mathematics Course Offered		
Predictive Model 1: Characteristics of Others		
Fathers Educational Expectations		
Counselor Encouragement		
Mother As a Role Model		
Parental Encouragement	.31	.28
Mothers Educational Expectations		
Predictive Model 2: Characteristics of Self		
Mathematics Preparation Required for a Job		
Educational Aspirations	.39	.36
Attitudes Toward Mathematics		
Age 13 Males		
"Nonintervenable" Variables		
School Enrollment		
Socioeconomic Status	.02	.00
Predictive Model 1: Characteristics of Others		
Mothers Educational Expectations	.10	.08
Parental Encouragement		
Predictive Model 2: Characteristics of Self		
Usefulness of Mathematics	.19	.17
Attitudes Toward Mathematics		
Educational Aspirations		
Grade 12 Females		
"Nonintervenable" Variables		
School Enrollment		
Number of Mathematics Courses Offered		
Socioeconomic Status	.07	.00
Most Advanced Course Offered		
Predictive Model 1: Characteristics of Others		
Fathers Educational Expectations	.28	.21
Teacher Encouragement		
Teacher Stereotyping		
Predictive Model 2: Characteristics of Self		
Educational Aspirations		
Attitudes Toward Mathematics	.37	.30
Mathematics Preparation Required for Job		
Age 13 Females		
"Nonintervenable" Variables		
School Enrollment		
Socioeconomic Status	.00	.00
Predictive Model 1: Characteristics of Others		
Counselor Encouragement	.07	.07
Fathers Educational Expectations		
Predictive Model 2: Characteristics of Self		
Usefulness of Mathematics		
Attitudes Toward Mathematics	.09	.09
Educational Aspirations		

*Only variables adding at least 1% to predicted variance are included.

percentages of variance explained by either predictive model for both sexes.

Results of the predictive models for intended mathematics participation for 13-year-old males are also included in Table 7. The nonintervenable variables of school enrollment and SES were accounted for in both predictive models. Mother's educational expectations and parental encouragement accounted for a small increase of 8 percent in the variance in the model including the influences of "others". The usefulness of mathematics, attitudes toward mathematics and educational aspirations accounted for a 17 percent increase in common variance in the "self" predictive model. For 13-year-olds, it is not surprising that the variable of usefulness is a better predictor of participation than the variable of mathematics preparation required for a job, which was the better predictor for students in grade 12. Thirteen-year-olds seem to have a general notion that mathematics will be useful, but they are probably poorly informed regarding course work needed for career preparation.

For 13-year-old females, father's educational expectations and counselor encouragement were the best predictors of intended participation, but these accounted for only a slight 7 percent increase of the explained variance. As was true for 13-year-old males, the best "self" predictors of intended participation were the perceived usefulness of mathematics, attitudes toward mathematics and educational aspirations.

CONCLUSIONS

The purpose of this survey was to identify the factors affecting the mathematics participation of male and female students and to assess the relative importance of those factors. The analysis of the survey results suggests certain areas for possible intervention and change. A summary of those results and suggestions follows.

Achievement

Achievement data from the present study as well as data from the second NAEP mathematics assessment suggest that 13-year-old females start their high school mathematics program with at least the same mathematical abilities as males. Thirteen-year-old females are better at computation and spatial visualization than their male counterparts. At this age, the problem-solving skills of females and males are nearly equal.

By the end of high school the situation has changed. Twelfth grade males show superior scores on problem-solving measures, and females have lost their advantage in computation and spatial visualization. However, the hypothesis that males' superior achievement in mathematics is due to a superior ability in spatial visualization is not supported by the results of this study. While males were found to be better problem-solvers by the end of high school, no sex differences were found in spatial visualization ability.

Participation

The large sex differences found in participation in earlier studies were not found in this national survey. The results from both the NAEP data and this survey on course-taking indicate that no sex differences in participation exist for general mathematics courses or for Algebra I and Geometry. The NAEP assessment found statistically significant differences favoring males for the advanced course of Trigonometry and Pre-Calculus/Calculus. The Women in Mathematics survey found significant differences favoring males for Algebra II and Probability/Statistics, but not for the higher-level courses of Trigonometry, Pre Calculus and Calculus. However, the nonstatistically significant differences found in course-taking for these advanced courses always favored males.

Thirteen-year-old men and women were equally optimistic about how much mathematics they planned to take while in high school. In fact, although the difference was not significant, four percent more women intended to take four years of high school mathematics. When this result is combined with the data indicating 13-year-old women achieve as well as or better than their male counterparts at this age, it seems that they start their high school mathematics experience on equal footing with men. That is, they start high school with the same ability and willingness to take mathematics. These results suggest that intervention strategies should focus on nurturing the skills and maintaining the attitudes that 13-year-olds exhibit throughout the high school years.

Attitudes and Participation

The results of both the correlation analyses and regression analyses suggest that three groups of variables have the greatest effect upon participation:

- positive attitudes toward mathematics
- perceived need for and usefulness of mathematics
- positive influences of significant other people (parents, teachers, counselors)

Future intervention strategies should emphasize the positive effects of these variables.

Intervention Strategies: Suggestions

Positive Attitudes Toward Mathematics

In the area of attitudes toward mathematics, teachers need to help instill mathematical confidence and enjoyment in their students. Students' feelings toward mathematics are largely a reaction to mathematics teaching, the mathematics program and classroom activities. Methods and programs which will in-

crease students' liking of mathematics need to be developed and evaluated.

Career Awareness and the Usefulness of Mathematics

Career awareness programs in junior high and senior high schools are an obvious area for intervention. Students who know they will need mathematics in their future career or to complete their education are more likely to take mathematics. Three or four years of academic mathematics in high school are required for most college mathematics, at least two years are needed for vocational or technical schools.

As an example of the type of intervention proposed, the Math/Science Network in the San Francisco Bay area has pioneered intervention programs to widen options and improve the career awareness of students. Articulate women in nontraditional fields attend conferences for high school girls and discuss aspects of their careers and the training required. Classroom activities encourage students to consider as many career options as possible; to learn about careers related to their interests and to determine and take the necessary mathematics and science courses that these careers will require.

Teachers are not the only change agents in terms of career awareness and educational aspirations. Students' educational aspirations are frequently a reflection of their parents' aspirations for them. Because of this, parents should encourage their children to set their educational goals as high as is realistic and to help them realize that taking mathematics is a necessity for getting into college or technical school as well as to prepare them for further studies. Increasingly, college majors, especially in the social sciences, require a background in mathematics.

School counselors can play an important role in making students more aware of career options and the requisite courses they need to take while in high school. Counselors need to become aware of career possibilities for women, since over 90 percent of the women they counsel will work for a significant portion of their lives. It is hoped that Title IX, which requires nonbiased counseling for women, has prompted counselors to give more attention to career opportunities for women.

Parents, Teachers, Counselors

Parents, teachers and school counselors are in ideal positions to encourage both men and women to take more mathematics. When scales measuring the effects of significant others were entered into regression equations, parental encouragement, parental education expectations and counselor encouragement were the best predictors of participation for twelfth grade men. For women, father's educational expectations and teacher encouragement were the best predictors of course taking.

It is the active encouragement of parents, teachers and counselors which seems to affect participation. The measure of parents' influence as role models, a passive influence, did not correlate with participation. Evidently parents don't need to set good examples regarding mathematics for their children to take mathematics in school. But, they can stress the importance of mathematics and encourage their children to take it by discussing high school course selections and future career options.

A point needs to be made regarding the effects of stereotyping of mathematics on women's participation. Although an absence of teacher stereotyping of mathematics was one of the predictors for participation of senior women, most of the stereotyping measures showed a low or insignificant correlation with participation. Stereotyping may not be one of the dominant factors affecting participation, but it does deserve some attention in terms of intervention. For senior women, the "mathematics as a male domain" scale had a significant correlation with participation. Women who saw mathematics as a field of study equally appropriate for women and men were more likely to take advanced mathematics courses. Areas for intervention could include programs which help women realize the appropriateness of pursuing a career in a mathematical or technical field.

Summary

The factors affecting participation are both numerous and complex. Results reported in this study indicate that the large differences in participation between men and women have diminished considerably in the past few years. It was also found that many of the factors which affect participation are the same for males and females.

Simply because large sex differences in participation were not found, the issue of mathematics participation should not be forgotten or ignored. The importance of taking high school mathematics cannot be overemphasized. Of the 42 percent of all students who indicated they were in a college preparatory program, only 25 percent had taken the four years of high school mathematics necessary for the college mathematics they would need for many majors.

Participation in mathematics is mostly an issue of awareness. If parents, teachers and counselors understand and transmit to students the necessity of taking mathematics to keep their options open and if they have the same high expectations for women as they have for men, then a basis for equal opportunity in scientific and technical fields will exist — for *men* and *women*.

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